

Fluid-structure interaction between pulsatile blood flow and a curved stented coronary artery on a beating heart: a four stent computational study

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Abstract. This work focuses on fluid-structure interaction (FSI) between a curved (tortuous) coronary artery with an implanted stent, pulsatile blood flow, and heart contractions. The goal is to understand which geometric distribution of stent struts, given by four different, commercially available stent geometries, is least likely to be associated with parameters correlated with pathobiologic responses leading to restenosis, in the case of *curved* coronary arteries, whose curvature changes significantly with each heart contraction. The stent geometries considered in this study correspond to a Palmaz-like stent, an Express-like stent, a Cypher-like stent, and a Xience-like stent. The biomechanical environment induced by each implanted stent is evaluated in terms of displacement magnitude, Von Mises stress, normal stress experienced by the intimal layer with implanted stent, and wall shear stress. Arterial walls are modeled as multi-layered structures: the intimal layer with the internal elastic laminae is modeled as a nonlinearly elastic membrane, while the media-adventitia complex is modeled as a 3D linearly elastic material. The Navier-Stokes equations for an incompressible, viscous fluid, are used to model the blood flow. Full, two-way coupling between the fluid and the structure, and between the thin and thick structure, is considered. To include the effects of the force exerted by the pericardium and heart muscle contractions, external force is applied to the coronary artery walls. Pulsatile blood flow conditions were imposed at the inlet and outlet of the coronary segment, approximating measured diastolic coronary flow. The presence of an implanted stent was modeled by its impact on the mass and elasticity properties of the intimal layer where the stent is located. The stent material is modeled as a 316L stainless steel. A novel, loosely coupled partitioned scheme combined with an ALE approach was used to solve this nonlinear FSI problem. It was found that the Cypher-like stent geometry outperforms the other three stent geometries. The ranking from best to worst is as follows: Cypher-like stent, Express-like stent, Xience-like stent, Palmaz-like stent. It is conjectured that the sinusoidal horizontal stent struts and large cells associated with open-cell design, give rise to a stent geometry that conforms best to the native curved coronary artery, with smallest deviations in Von Mises stress and displacement from the nonstented curved coronary artery both during systole and diastole. To the best of our knowledge, this is the first computational study in which the

behavior of different stent geometries implanted in curved coronary arteries is studied using full FSI capturing the behavior of multi-layered, curved, stented coronary arteries contracting on a beating heart.

Keywords: Fluid-structure interaction; Curved coronary artery; Coronary stent; Loosely coupled partitioned scheme; Arbitrary Lagrangian-Eulerian formulation.

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